

# **TEKTRONIX®**

## **5A26 DUAL DIFFERENTIAL AMPLIFIER**

### **INSTRUCTION MANUAL**

Tektronix, Inc.  
P.O. Box 500  
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Serial Number \_\_\_\_\_



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**All TEKTRONIX instruments are warranted against defective materials and workmanship for one year. Any questions with respect to the warranty should be taken up with your TEKTRONIX Field Engineer or representative.**

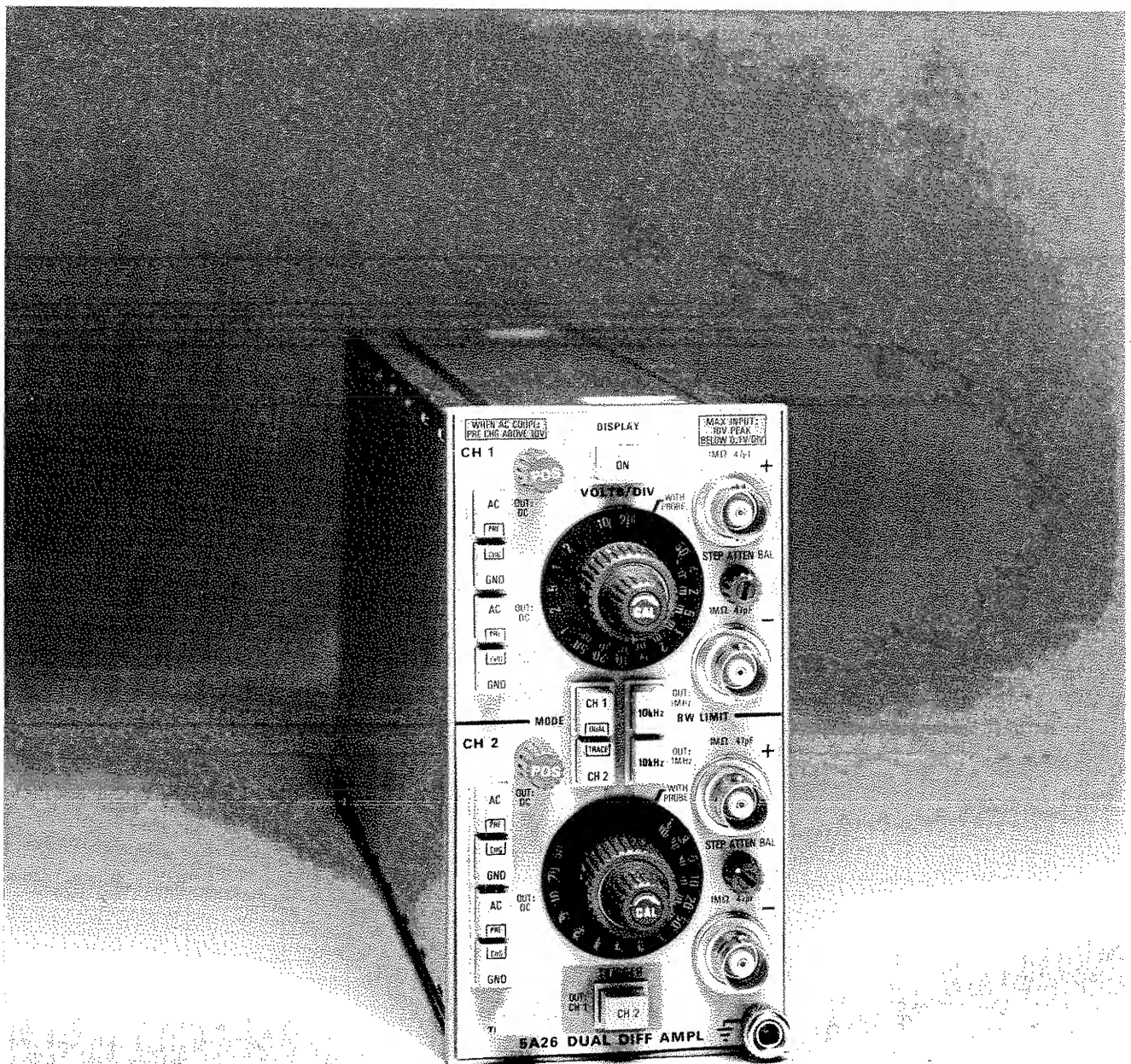
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Fig. 1-1. 5A26 Dual Differential Amplifier.



# OPERATING INSTRUCTIONS

The 5A26 Dual Differential Amplifier is a dual-trace high-gain differential amplifier plug-in for use with Tektronix 5000 Series Oscilloscopes. The unit contains two identical independent amplifier channels that feature high sensitivity and a high common-mode rejection ratio.

Each channel has a bandwidth capability of dc to 1 megahertz, and a front-panel push button switch allows the reduction of the upper bandwidth limit, thus increasing the signal-to-noise ratio for low frequency applications. Either channel may be used for single channel displays, or electronically switched to produce dual-trace displays.

An illuminated knob skirt provides a deflection factor readout, which is also displayed on the crt when used in an oscilloscope with readout capabilities.

## PREPARATION FOR USE

The 5A26 is calibrated and ready for use when received. The unit may be installed in any plug-in compartment. Refer to the oscilloscope instruction manual for information on X-Y operation. To install, align the upper and lower grooves of the 5A26 with the plug-in compartment tracks, and fully insert the 5A26 until it locks into place. To remove, pull the release latch to disengage the 5A26 from the oscilloscope.

## CONTROLS, CONNECTORS, AND INDICATORS

The following describes the function of the front-panel controls, connectors, and indicators. Refer to Fig. 1-2 for the location of the controls, connectors and indicators. More information is given under Detailed Operating Information.

- 1 **DISPLAY Push Button**—Applies and removes logic levels to the oscilloscope system to enable or disable plug-in operation. Switch is functional only when plug-in is operated in one of the vertical deflection plug-in compartments.
- 2 **POS Controls**—Positions display vertically.
- 3 **BW LIMIT Push Buttons**—Allows reduction of the upper bandwidth limit to increase the signal-to-noise ratio for low-frequency applications. Selects upper bandwidth limit at either 1 megahertz (button out) or 10 kilohertz (button in).
- 4 **VOLTS/DIV Switches**—Volts per major graticule division. Selects calibrated deflection factors from 50 microvolts/division to 5 volts/division; 16 steps in a 1-2-5 sequence. Knob skirt is illuminated to indicate deflection factor, and 10X scaling of both knob skirt and crt readout is provided automatically when a 10X coded probe is used.
- 5 **CAL (Variable VOLTS/DIV) Controls**—Provides uncalibrated continuously variable deflection factors between the calibrated settings of the VOLTS/DIV switch and extends the deflection-factor range to 12.5 volts/division.
- 6 **STEP ATTEN BAL Adjustments**—Balances the input amplifier for minimum trace shift throughout the deflection factor gain-switching range.
- 7 **Input Coupling Push Buttons**  
AC—OUT:DC. Button pushed in selects capacitive coupling of signal applied to associated + or — input connector; button out selects direct coupling of input signal.  
  
GND. Grounds the preamplifier input and connects input signal to ground through a 1 megohm resistor.  
  
PRE CHG. Both AC and GND buttons pushed in permits precharging of the coupling capacitor to the input signal dc level. Release GND button for measurement.
- 8 **MODE Push Buttons**—Select channel to be displayed and illuminate the proper deflection factor setting (1X or 10X) on the VOLTS/DIV switch knob skirt. Both buttons pushed in provides a dual-trace display.



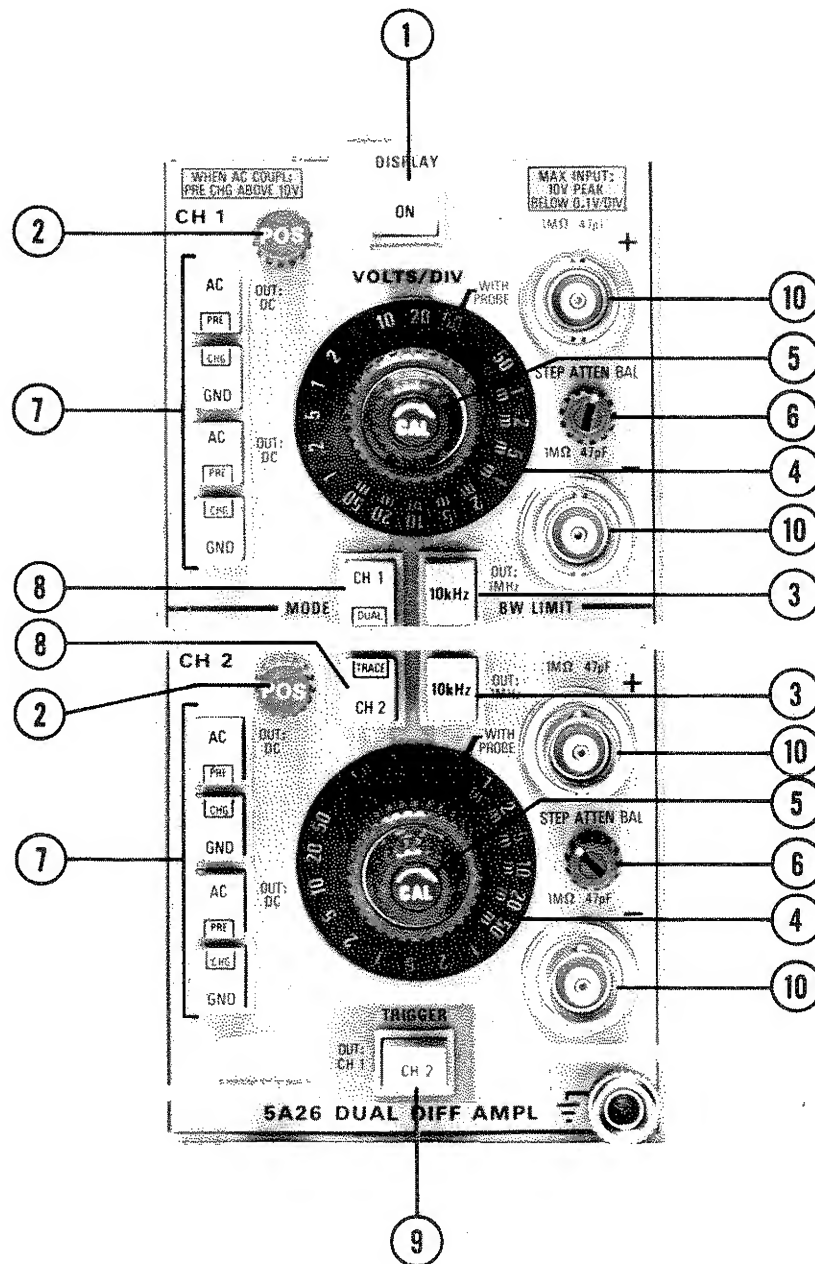


Fig. 1-2. Front-panel controls, connectors, and indicators.

- 9 **TRIGGER Push Button**—Selects time base triggering signal from either channel.

- 10 **+ and — Input Connectors**—BNC connectors for application of external voltage signals. Connector labeled + indicates that a positive-going signal will cause upward deflection; connector labeled — indicates that a positive-going signal will cause downward deflection. Connectors include coded-probe input rings for activating the readout when using readout-coded probes.

## BASIC OPERATION

### Preparation

The following procedures are intended to help place the trace on the screen quickly and prepare the instrument for immediate use:

- Insert 5A26 all the way into oscilloscope plug-in compartment.
- Turn oscilloscope Intensity control to midrange and turn oscilloscope system power on. Preset time-base and triggering controls for 2 millisecond/division sweep rate and automatic triggering.
- Set 5A26 front-panel controls as follows:

DISPLAY	ON (button in)
TRIGGER	OUT: CH 1 (button out)
POS	Midrange
BW LIMIT	OUT: 1 MHz (button out)
VOLTS/DIV	5
STEP ATTEN BAL	Midrange
CH 1 and CH 2 + Input Coupling	
AC	OUT: DC (button out)
GND	GND (button in)

CH 1 and CH 2 — Input Coupling

AC	OUT: DC (button out)
GND	GND (button in)
MODE	CH 1 and CH 2 (buttons in)

- Adjust intensity control for normal viewing. Traces should appear near graticule center.

- Set the VOLTS/DIV switches to .1. If traces shift, adjust the STEP ATTEN BAL control as described in Step Attenuator Balance Adjustment procedure.

- Move CH 1 trace 2 divisions below graticule horizontal centerline, and CH 2 trace to bottom of graticule with POS controls.

- Apply 400 millivolt peak-to-peak signal from oscilloscope calibrator loop with a test lead or 1X probe to CH 1 + input connector.

- Release CH-1 + GND button. Display will be a square wave 4 divisions in amplitude with bottom of display at reference established in step (f).

- Position bottom of square wave to graticule horizontal centerline.

- Push in CH 1 + AC button and note that display shifts downward 2 divisions.

- Disconnect test lead from CH 1 + input and connect to CH 2 + input.

- Push in TRIGGER button for CH 2 triggering and repeat steps (f) through (j) for CH 2 operation.

### Step Attenuator Balance Adjustment

When the STEP ATTEN BAL control is not properly adjusted, the display will shift vertically (due to a dc imbalance in the amplifier) as the VOLTS/DIV switch is rotated through-out its range. The shift is more noticeable on the most sensitive positions.

a. Set VOLTS/DIV switch to 5. Ground both + and — inputs (GND buttons pushed in) and position trace to graticule horizontal centerline.

b. Adjust STEP ATTEN BAL control for minimum trace shift as VOLTS/DIV switch is rotated throughout its range.

### Gain Check

When the 5A26 is first inserted into a plug-in compartment, the amplifier gain may be checked and adjusted if necessary. See Adjustment Procedure in Section 4 of this manual for complete instructions.

## DETAILED OPERATING INFORMATION

### Applying Signals

#### CAUTION

*If the maximum input voltage rating at the gates of the input FET's is exceeded, the gates are clamped at about + or — 10 volts. If the signal source can supply more than 1/16 ampere, the input protective fuse(s) will open.*

When measuring unknown voltages, use the highest deflection factor first. If the deflection is too small to make the measurement, switch to a lower deflection factor.

### Pre-Charging

When only the ac component of a signal having both ac and dc components is to be measured, the pre-charge circuit permits charging the coupling capacitor to the input signal dc level.

#### CAUTION

*If the 5A26 input is connected to a large dc voltage source (10 volts peak or more), use the precharge provision. Damage to the signal source could result since the peak current through the ac coupling capacitor and the input protection circuitry is limited only by the signal source internal resistance.*

a. Before connecting 5A26 to a signal containing a dc component, push in AC and GND buttons. Then connect input to circuit under test.

b. Wait about 1 second for coupling capacitor to charge.

c. Release GND button and ac component can be measured in usual manner.

### Signal Input Connectors

When connecting signals to the + and — input connectors on the 5A26, consider the method of coupling that will be used. Sometimes unshielded test leads can be used to connect the 5A26 to a signal source, particularly when a high level, low-frequency signal is monitored at a low impedance point. However, when any of these factors are missing, it becomes increasingly important to use shielded signal cables. In all cases, the signal-transporting leads should be kept as short as practical.

When making single-ended input measurements (conventional amplifier operation), be sure to establish a common ground connection between the device under test and the 5A26. The shield of a coaxial cable is normally used for this purpose.

In some cases, differential measurements require no common ground connection, and therefore are less susceptible to interference by ground-loop currents. Some problems with stray magnetic coupling into the signal transporting leads can also be minimized by using a differential rather than a single-ended measurement. These considerations are discussed later in this section under Differential Operation.

It is always important to consider the signal source loading (and resulting change in the source operating characteristics) due to the signal-transporting leads and the input circuit of the 5A26. The circuit at the input connectors can normally be represented by a 1 megohm resistance to ground paralleled by about 47 picofarads. A few feet of shielded cable (20 to 40 picofarads per foot) may increase the parallel capacitance to 100 picofarads or more. In many cases, the effects of these resistive and capacitive loads may be too great and it may be desirable to minimize them through the use of an attenuator probe.

Attenuator probes not only decrease the resistive-capacitive loading of a signal source, but also extend the measurement range of the 5A26 to include substantially higher voltages. Passive attenuator probes having attenuation factors of 10X, 100X, and 1000X, as well as other special-purpose types, are available through your Tektronix Field Engineer or Field Office.

Some measurement situations require an extremely high resistance input to the 5A26 with very little source loading



or signal attenuation. In such situations, a passive attenuator probe cannot be used. However, this problem may be solved by using a FET Probe or the high-impedance input provision of the 5A26 as described under High-Impedance Input.

### High-Impedance Input

In the 50 m through 50  $\mu$  positions of the VOLTS/DIV switch, where the input attenuator is not used, the internal gate return resistors alone establish the 1 megohm input resistance. The removal of the strap from the Preamplifier circuit board (see Fig. 4-4, Channel 1 and 2 Preamplifier circuit board component and test point locations in the Diagrams and Parts Lists section) disconnects these resistors from ground and permits the input FET gates to float, providing a very high input impedance.

The input signal must be kept to relatively low amplitudes, since the deflection factor is restricted to 50 millivolts/division through 50 microvolts/division, and dc coupling must be used to provide a dc path for the FET gate current.

#### NOTE

*In the 0.1 volt to 5 volt range of the VOLTS/DIV switch, the input impedance is paralleled by the resistors in the attenuator. When the strap is removed, the attenuation ratio is affected, causing the deflection factors in this range to be incorrect. To determine the deflection factor, check the deflection with an input signal of known amplitude.*

The signal source impedance is an important factor, since gate current will produce an offset. For example, a 100 picoampere gate current through 10 megohms produces a 1 millivolt offset, which may result in significant error where small voltages are of concern.

The high-frequency response will also depend upon the signal source impedance, since various shunt capacitances between the source and the input gate must charge and discharge through that impedance.

### Display Polarity

Single-ended signals applied to the + input connector produce a display in phase with the input signal. Signals applied to the — input connector will be inverted.

A similar polarity relationship exists for differentially applied signals, but pertains to the direction of voltage change at one input with respect to the other, rather than with respect to chassis potential.

### Deflection Factor

The amount of trace deflection produced by a signal is determined by the signal amplitude, the attenuation (if any) of the probe, the setting of the VOLTS/DIV switch, and the setting of the Variable control. The deflection factor settings are calibrated only when the Variable control is rotated fully clockwise into the detent position.

The range of the Variable control is at least 2.5:1. It provides uncalibrated deflection factors covering the full range between the calibrated settings of the VOLTS/DIV switch. The Variable control can be set to extend the deflection factor to at least 12.5 volts/division.

To reduce noise and obtain a more usable display when the VOLTS/DIV switch is set to the more sensitive positions, push in the BW LIMIT button to reduce the bandwidth to 10 kHz if this limit does not appreciably distort the desired features of the signal under observation.

### Voltage Comparison Measurements

Some applications require deflection factors other than the fixed values provided by the VOLTS/DIV switch. One such application is comparison of signal amplitudes by ratio rather than by absolute voltage. To accomplish this, apply a reference signal to either + or — inputs of the 5A26, and set the VOLTS/DIV switch and Variable control so that the reference display covers the desired number of graticule divisions. Do not change the Variable control settings throughout the subsequent comparisons. However, the settings of the VOLTS/DIV switch can be changed to accommodate large ratios. In doing so, regard the numbers which designate the switch positions as ratio factors rather than voltages.

### Differential Operation

Single-ended measurements often yield unsatisfactory results because of interference resulting from ground-loop currents between the 5A26 and the device under test. In other cases, it may be desirable to eliminate a dc voltage by means other than the use of a dc blocking capacitor, which could limit the low-frequency response.

These limitations of single-ended measurements are effectively eliminated by connecting the + input and — input to selected points in the test circuit. Since the chassis of the 5A26 need not be connected in any way to the test circuit, there are few limitations to the selection of these test points. In any case, do not exceed the maximum safe input voltages.

The + and — AC buttons should both be set to the same positions, depending on the method of signal coupling required.

## Operating Instructions—5A26

Only the voltage difference between two signals is amplified and displayed in differential measurements, while the common-mode signals (common in amplitude, frequency and phase) are rejected.

The ability of the 5A26 to reject common-mode signals is indicated by the common-mode rejection ratio (cmrr). Cmrr is at least 100,000:1 at the input connectors from 50 microvolts/division to 50 millivolts/division when signals between dc and 30 kilohertz are dc coupled to the inputs. To illustrate this characteristic, assume that a single-ended input signal consists of an unwanted 60 hertz signal of 1 volt peak-to-peak, plus a desired signal of 1 millivolt peak-to-peak. If an attempt is made to display the described signal (single-ended measurement) at 0.2 millivolts/division, the 60 hertz signal will produce a deflection equivalent to 5000 divisions and the 1 millivolt signal will be lost.

If the same 1 millivolt signal is measured differentially with the 60 hertz signal common to both inputs, no more than one part in 100,000 of the common-mode signal will appear in the display. The desired signal will produce a display of 5 divisions, with not more than 0.1 division of display produced by the common-mode signal (cmrr not specified when residual display is 0.1 division or less).

There are a number of factors which can degrade common-mode rejection. The principle requirement for maximum rejection is that the common-mode signal arrives at the input FET gates in precisely the same form. A difference of only 0.01% in the attenuation factors of the input attenuators may reduce the rejection ratio to 10,000:1. Likewise, any difference in source impedance at the two points in the source under test will degrade the rejection ratio. Attenuator probes which do not have adjustable resistance and capacitance may reduce the rejection ratio to 100:1 or less.

Outside influences such as magnetic fields can also degrade the performance, particularly when low level signals are involved. Magnetic interference may be minimized by using identical signal-transporting leads to the two inputs and twisting the two leads together over as much of their length as possible.

### Voltage Probes

In general, probes offer the most convenient means of connecting a signal to the input of the 5A26. Tektronix

probes are shielded to prevent pickup of electrostatic interference. A 10X attenuator probe offers a high input impedance and allows the circuit under test to perform very close to normal operating conditions. See your Tektronix, Inc., catalog for characteristics and compatibility of probes for use with this system.

**CODED PROBES.** The 5A26 is designed for compatibility with coded probes, such as the Tektronix P6062A 1X/10X Passive Probe. The + and — input connectors have an outer ring to which the coding pin on the probe connector makes contact. This type of probe allows the vertical deflection factor indicated by the readout to correspond with the actual voltage at the probe tip, eliminating the need to consider the attenuation factor when measuring the signal amplitude on the graticule scale.

### Differential Measurements

The following adjustment procedure is recommended when preparing to use two Tektronix P6062A probes for differential measurements in the 10X mode.

- a. Connect one probe for dc-coupled, single-ended operation to CH 1 + input. Obtain triggered display of an appropriate square wave, such as that from a calibrator or square-wave generator. Compensate probe square-wave response with probe compensation adjustment.
- b. Connect a second probe for dc-coupled operation to CH 1 — input. Apply 100 volt peak-to-peak square wave to both probes. Free-run sweep and adjust probe compensation adjustment of second probe for minimum display amplitude.
- c. Steps (a) and (b) match the probes for use at any sensitivity that employs the particular input attenuator (1X or 100X) used in steps (a) and (b). When it is necessary to use the other input attenuator, steps (a) and (b) should be repeated.
- d. Repeat steps (a), (b), and (c) for Channel 2.
- e. When examining a small differential signal in the presence of relatively large common-mode components, adjust probe by temporarily connecting both probes to either of the two signal sources.

## SPECIFICATIONS

TABLE 1-1  
Electrical Specifications

Characteristics	Performance Requirement
Deflection Factor	
Calibrated Range	50 $\mu$ V/div to 5 V/div in a 1, 2, 5 sequence.
Accuracy	Within 2% of deflection factor setting.
Uncalibrated Range	Variable VOLTS/DIV control provides continuously variable deflection factor between calibrated settings and extends deflection factor range to 12.5 V/div.
Frequency Response	
Bandwidth (8 Div Reference)	
DC (Direct) Coupled	
1 MHz	Dc to at least 1 MHz.
10 kHz	Dc to 10 kHz within 20%.
AC (Capacitive) Coupled	
1 MHz	2 Hz or less to at least 1 MHz.
10 kHz	2 Hz or less to 10 kHz within 20%.
Step Response	
Aberrations	+2%, -2% or less. Total not to exceed 4% p-p.
Input R and C	1 M $\Omega$ within 0.15% paralleled by approximately 47 pF.
Maximum Safe Input Voltage	
DC (Direct) Coupled	
50 $\mu$ V/Div to 50 mV/Div	10 V (dc + peak ac).
100 mV/Div to 5 V/Div	350 V (dc + peak ac).
AC (Capacitive) Coupled	
50 $\mu$ V/Div to 50 mV/Div	350 V dc (coupling capacitor pre-charged) 10 V peak ac.
100 mV/Div to 5 V/Div	350 V (dc + peak ac).
DC Rejection	
AC (Capacitive) Coupled	At least 100,000:1 after 20 minute warmup.
Input Gate Current	100 pA or less (100 $\mu$ V or less depending on external loading) at +25°C.
Common Mode Rejection	
DC (Direct) Coupled	
50 $\mu$ V/Div to 50 mV/Div	At least 100,000:1 from dc to 30 kHz with up to 20 V p-p sine wave.
100 mV/Div to 5 V/Div	At least 300:1 from dc to 30 kHz with up to 100 V p-p sine wave.

**TABLE 1-1 (CONT.)**  
**Electrical Specifications**

Characteristics	Performance Requirement
Common Mode Rejection (continued)	
AC (Capacitive) Coupled	
50 $\mu$ V/Div to 50 mV/Div	At least 20,000:1 at 5 kHz and above, decreasing to not less than 2000:1 at 60 Hz.
With 2 P6062A Probes	400:1 at 10X probe attenuation.
Displayed Noise (Tangentially Measured)	30 $\mu$ V or less at full bandwidth.
Channel Isolation at 1 MHz (Single-Ended)	At least 100:1 with 8 div sine wave applied to one channel at 2 V/div and other channel at 1 mV/div with no signal applied.
Channel Isolation at 30 kHz (Common Mode)	50 $\mu$ V or less at any deflection factor with 20 V p-p sine wave applied to + and — inputs of either channel.

**TABLE 1-2**  
**Environmental Specifications**

Characteristics	Performance Requirement
Temperature	
Operating	0°C to +50°C.
Storage	–55°C to +70°C.
Altitude	
Operating	To 15,000 Feet.
Storage	To 50,000 Feet.
Vibration	
Operating	15 minutes along each of 3 major axes at a total displacement of 0.015 inch with frequency varied from 10 Hz to 50 Hz to 10 Hz in 1 minute sweeps. Hold for 3 minutes at 50 Hz. All major resonances must be above 50 Hz.
Shock	
Operating and Storage	To 30 g's, 1/2 sine, 11 ms duration, 2 shocks per axis in each direction for a total of 12 shocks.

**TABLE 1-3**  
**Physical Specifications**

Characteristics	Description
Weight	Approximately 2 lbs, 3 oz. (1 kg).
Dimensions	See Fig. 1-3, Dimensions.

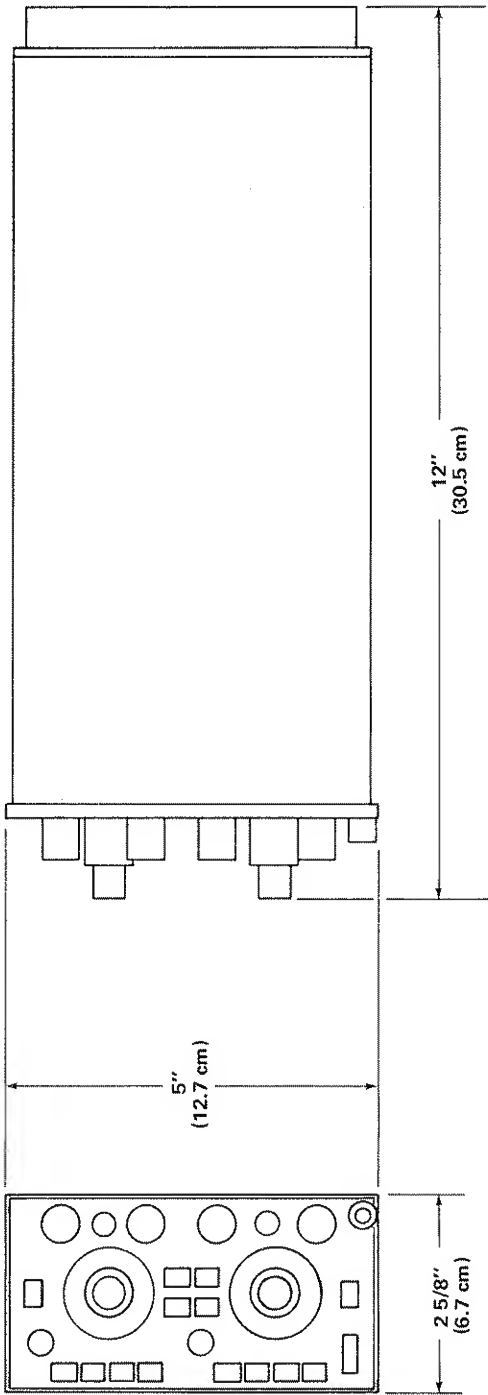


Fig. 1-3. Dimensions.

1.  $\frac{1}{2}$  2.  $\frac{1}{3}$  3.  $\frac{1}{4}$  4.  $\frac{1}{5}$  5.  $\frac{1}{6}$  6.  $\frac{1}{7}$  7.  $\frac{1}{8}$  8.  $\frac{1}{9}$  9.  $\frac{1}{10}$  10.  $\frac{1}{11}$  11.  $\frac{1}{12}$  12.  $\frac{1}{13}$  13.  $\frac{1}{14}$  14.  $\frac{1}{15}$  15.  $\frac{1}{16}$  16.  $\frac{1}{17}$  17.  $\frac{1}{18}$  18.  $\frac{1}{19}$  19.  $\frac{1}{20}$  20.  $\frac{1}{21}$  21.  $\frac{1}{22}$  22.  $\frac{1}{23}$  23.  $\frac{1}{24}$  24.  $\frac{1}{25}$  25.  $\frac{1}{26}$  26.  $\frac{1}{27}$  27.  $\frac{1}{28}$  28.  $\frac{1}{29}$  29.  $\frac{1}{30}$  30.  $\frac{1}{31}$  31.  $\frac{1}{32}$  32.  $\frac{1}{33}$  33.  $\frac{1}{34}$  34.  $\frac{1}{35}$  35.  $\frac{1}{36}$  36.  $\frac{1}{37}$  37.  $\frac{1}{38}$  38.  $\frac{1}{39}$  39.  $\frac{1}{40}$  40.  $\frac{1}{41}$  41.  $\frac{1}{42}$  42.  $\frac{1}{43}$  43.  $\frac{1}{44}$  44.  $\frac{1}{45}$  45.  $\frac{1}{46}$  46.  $\frac{1}{47}$  47.  $\frac{1}{48}$  48.  $\frac{1}{49}$  49.  $\frac{1}{50}$  50.  $\frac{1}{51}$  51.  $\frac{1}{52}$  52.  $\frac{1}{53}$  53.  $\frac{1}{54}$  54.  $\frac{1}{55}$  55.  $\frac{1}{56}$  56.  $\frac{1}{57}$  57.  $\frac{1}{58}$  58.  $\frac{1}{59}$  59.  $\frac{1}{60}$  60.  $\frac{1}{61}$  61.  $\frac{1}{62}$  62.  $\frac{1}{63}$  63.  $\frac{1}{64}$  64.  $\frac{1}{65}$  65.  $\frac{1}{66}$  66.  $\frac{1}{67}$  67.  $\frac{1}{68}$  68.  $\frac{1}{69}$  69.  $\frac{1}{70}$  70.  $\frac{1}{71}$  71.  $\frac{1}{72}$  72.  $\frac{1}{73}$  73.  $\frac{1}{74}$  74.  $\frac{1}{75}$  75.  $\frac{1}{76}$  76.  $\frac{1}{77}$  77.  $\frac{1}{78}$  78.  $\frac{1}{79}$  79.  $\frac{1}{80}$  80.  $\frac{1}{81}$  81.  $\frac{1}{82}$  82.  $\frac{1}{83}$  83.  $\frac{1}{84}$  84.  $\frac{1}{85}$  85.  $\frac{1}{86}$  86.  $\frac{1}{87}$  87.  $\frac{1}{88}$  88.  $\frac{1}{89}$  89.  $\frac{1}{90}$  90.  $\frac{1}{91}$  91.  $\frac{1}{92}$  92.  $\frac{1}{93}$  93.  $\frac{1}{94}$  94.  $\frac{1}{95}$  95.  $\frac{1}{96}$  96.  $\frac{1}{97}$  97.  $\frac{1}{98}$  98.  $\frac{1}{99}$  99.  $\frac{1}{100}$  100.  $\frac{1}{101}$  101.  $\frac{1}{102}$  102.  $\frac{1}{103}$  103.  $\frac{1}{104}$  104.  $\frac{1}{105}$  105.  $\frac{1}{106}$  106.  $\frac{1}{107}$  107.  $\frac{1}{108}$  108.  $\frac{1}{109}$  109.  $\frac{1}{110}$  110.  $\frac{1}{111}$  111.  $\frac{1}{112}$  112.  $\frac{1}{113}$  113.  $\frac{1}{114}$  114.  $\frac{1}{115}$  115.  $\frac{1}{116}$  116.  $\frac{1}{117}$  117.  $\frac{1}{118}$  118.  $\frac{1}{119}$  119.  $\frac{1}{120}$  120.  $\frac{1}{121}$  121.  $\frac{1}{122}$  122.  $\frac{1}{123}$  123.  $\frac{1}{124}$  124.  $\frac{1}{125}$  125.  $\frac{1}{126}$  126.  $\frac{1}{127}$  127.  $\frac{1}{128}$  128.  $\frac{1}{129}$  129.  $\frac{1}{130}$  130.  $\frac{1}{131}$  131.  $\frac{1}{132}$  132.  $\frac{1}{133}$  133.  $\frac{1}{134}$  134.  $\frac{1}{135}$  135.  $\frac{1}{136}$  136.  $\frac{1}{137}$  137.  $\frac{1}{138}$  138.  $\frac{1}{139}$  139.  $\frac{1}{140}$  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## THEORY OF OPERATION

This section of the manual describes the operation of the circuits in the 5A26 Dual Differential Amplifier unit. Complete schematic diagrams and an overall block diagram of the unit are given on pullout pages at the back of this manual. The channel 1 and channel 2 circuitry is essentially identical. The following block diagram and circuit operation discussions apply to channel 1 with exceptions included where applicable.

### BLOCK DIAGRAM DESCRIPTION

When the DISPLAY button is pressed, a logic level is applied to the oscilloscope to enable 5A26 operation (switch function is limited to operation in a vertical deflection compartment).

Signals applied to the + and — input connectors can be passed directly through the input coupling switches to the attenuators (dc coupled) or they can be capacitively (ac) coupled to block the dc component of the signal. The GND switch provides a ground reference to the Preamplifier input.

The Input Attenuator consists of frequency-compensated voltage dividers. 1X attenuation is provided for the 50  $\mu$  to 50 m positions of the VOLTS/DIV switch, and 100X attenuation is provided for the .1 to 5 positions. Balance to a low-frequency common-mode signal between the attenuators of the two inputs is set by adjustment of the internal LF CMR potentiometer.

From the Input Attenuator, the signal is passed directly to the Preamplifier. The inputs to the Preamplifier are fuse and diode protected. The Preamplifier consists of two identical operational amplifiers connected in a differential configuration. Common-mode signals between ground and the two inputs are rejected, due to a bootstrapped floating power supply that moves with the common-mode signal to maintain constant operating characteristics of the active devices. The difference between the two inputs is amplified. The constant current return facilitates the dc balance of the Preamplifier outputs.

From the Preamplifier, the signal is coupled directly to the Gain Switching Amplifier. Two identical operational amplifiers and a series-parallel resistor network provide the proper gain for each VOLTS/DIV switch setting.

The BW LIMIT 10 kHz switch places a capacitor across the two output lines to reduce the bandwidth and, thus, limit the noise. The signal is then passed to the Output Amplifier through an emitter-follower isolation stage.

The output differential amplifier is operated push-pull, presenting a signal to the output terminal that is of the same polarity as that applied to the Preamplifier input. The front-panel Variable VOLTS/DIV (CAL) and internal gain controls provide a means of varying the gain of the 5A26. A positioning-current driver is connected to the output lines to alter the quiescent trace position.

A triggering signal is tapped from the emitter-follower isolation stage, amplified and made available to an associated time-base plug-in unit. Triggering signal amplitude is about 0.25 volts per displayed division.

Channel switching is accomplished by the plug-in MODE buttons and the channel switch signal from the oscilloscope. Electronic switching provides a display of either or both channels (dual-trace). The switching rate in dual-trace operation is determined by the channel-switch signal repetition rate from the oscilloscope.

The VOLTS/DIV switch control is made up of a series of cams and contacts that switch input attenuators, select the proper gain-setting resistors in the Gain Switching Amplifier, and provide the proper crt readout data.

Either of two lamp bulbs behind the knob skirt on the VOLTS/DIV switch illuminate the selected deflection factor. One lamp lights for 1X deflection factor; the other lights when a readout-coded probe is attached to the + or — input connectors to indicate a 10X deflection factor.

## CIRCUIT OPERATION

Circuits unique to this instrument are described in detail in this discussion. Circuits commonly used in the electronics industry are not described in detail. If more information is desired on these commonly used circuits, refer to the following textbooks.

Phillip Cutler, "Semiconductor Circuit Analysis", McGraw-Hill, New York, 1964.

Jacob Millman and Herbert Taub, "Pulse Digital and Switching Waveforms", McGraw-Hill, New York, 1965.

Albert Paul Malvino, "Transistor Circuit Approximations", McGraw-Hill, New York, 1973.

Gordon V. Deboo, "Integrated Circuits and Semiconductor Devices", McGraw-Hill, New York, 1971.

Lloyd P. Hunter (Ed.), "Handbook of Semiconductor Electronics", third edition, McGraw-Hill, New York, 1970.

The numbers inside the diamonds after a heading refer to the schematic diagram for that circuit located at the back of this manual.

### PREAMPLIFIER



#### Plug-In Logic

When DISPLAY button is pressed, a logic level is applied to the electronic switching circuit in the oscilloscope to enable plug-in operation. Power is applied to illuminate the VOLTS/DIV knob skirt behind the proper deflection factor when the MODE button is pressed in.

#### Input Coupling

Signals applied to the front-panel + and — input connectors may be capacitive coupled (ac), direct coupled (dc) or internally grounded through a capacitor and resistor. Input coupling is selected by means of two push button switches at each input; S2C and D for the + input and S2A and B for the — input.

A signal applied to the + input with both buttons in the out position (dc coupled) is passed directly to the Input Attenuator. When the AC button is pressed in, C12 is placed in the circuit to ac couple signals of about 2 hertz (—3 dB point) and higher to the attenuator. Capacitor C12 blocks any dc component of the signal. When the GND button is pressed in, a ground reference is provided to the input of the amplifier without the need to remove the applied signal from the input connector.

#### NOTE

*When ac coupled with dc levels of 10 volts or more, both the AC and GND buttons should be pressed in (PRE CHG) while input connections are made or broken, or when voltage levels are changed. This allows the coupling capacitor to charge without opening the input fuses or overdriving the amplifier.*

#### Input Attenuators

The Input Attenuators consist of frequency-compensated voltage dividers that provide 100X attenuation in the .1 to 5 positions of the VOLTS/DIV switch. For dc and low-frequency signals, the dividers are essentially resistive (attenuation ratio determined by the resistance ratio). Balance between the attenuators of the two inputs for low-frequency common-mode signals is set by adjusting R9, LF CMR. At higher frequencies, the capacitive reactance becomes effective and the impedance ratio determines the attenuation.

In addition to providing constant 100X attenuation at all frequencies within the bandwidth capabilities of the instrument, the Input Attenuator maintains a constant input RC characteristic (1 megohm paralleled by about 47 picofarads) for the .1 to 5 positions of the VOLTS/DIV switch.

#### Input Protection

Input protection consists of fuses F20 and F30 and diodes CR21, CR24, CR31, and CR34. If the signal should reach a level sufficient to forward bias one of the protection diodes (a potential greater than about 12.5 volts), current will be conducted through that diode, protecting the input FET's. If that current should exceed the fuse rating, the fuse(s) will open.

#### Preamplifier

The Preamplifier consists of two identical operational amplifiers connected in a differential configuration.

The operational amplifiers consist of Q54A, Q60A, and Q64A on the — input side, and Q54B, Q60B and Q64B on the + input side. Transistors Q54A and Q54B provide a

voltage follower input to output transistors Q64A and Q64B while Q60A provides additional open-loop gain. Total gain of the stage is determined by R58 and R78 between the two amplifiers, and resistors R64 and R84.

Quiescently, the two sides of the amplifier are balanced. When a differential signal is applied to the gates of Q54A and Q54B, signal current is developed through resistors R58 and R78. Conduction of Q64A and Q64B is changed by the amount of signal current with the output voltage developed across R64 and R84. The output is a push-pull signal, opposite in polarity to the signal applied to the inputs.

To minimize trace shift as different vertical deflection factors are selected, the outputs at the Q64A and Q64B collectors are dc balanced at equal potentials so that the voltage across the gain-setting resistors in the Gain-Switching Amplifier is zero at all settings of the VOLTS/DIV switch. This dc balancing is achieved by adjusting R89, Atten Bal Range and R72, STEP ATTEN BAL.

### Common-Mode Rejection

One of the primary functions of the Preamplifier is to reject any common-mode component of the input signal and amplify only the difference. Assume that the inputs are tied together and a voltage is applied to the common input. The amplifier differential output is ideally zero, and would actually be zero provided that the characteristics of all corresponding elements on the two sides of the amplifier were matched (e.g., Q54A and Q54B transconductance and  $\mu$ , Q60A and Q60B beta, current sources, etc.). In practice, any mismatch will cause a differential output.

### Floating Power Supply

A Floating Power Supply consisting of Q39, Q44, Q48, and Zener diodes VR40 and VR42 minimizes inherent common-mode difficulties and, therefore, improves the common-mode rejection ratio (refer to Fig. 2-1). Transistor Q44 is a constant-current high-impedance source, and Q39 is the current return.

The input to the bootstrap (X1 gain) amplifier is connected to the junction of R58 and R78. The bootstrap amplifier portion of the supply consists of emitter-follower Q48 and dc level-shifting Zener diodes VR40 and VR42. The collector impedance of Q39 presents minimum loading to the Q48 output and maintains the gain of the amplifier (bootstrap efficiency) very close to one.

The entire power supply and amplifier voltages move an amount equal to the common-mode voltage to maintain a

constant operating characteristic of the elements in the Preamplifier stage. Since no common-mode signal current is developed, the output at the collectors of Q64A and Q64B remains unchanged; that is, the common-mode signal is rejected.

Variable capacitor C59, HF CMR, is adjusted to normalize the effective capacitance of the active devices on one side of the amplifier to the other.

## OUTPUT AMPLIFIERS



### Gain-Switching Amplifier

The Gain-Switching Amplifier consists of two identical operational amplifiers.

The operational amplifiers consist of Q205A, Q208A, and Q210A on the — input side and Q205B, Q208B, and Q210B on the + input side. Total gain of the stage is determined by R210, R220 and the setting of the VOLTS/DIV control which selects the series-parallel combination of R203, R213, and R228 through R236.

Potentiometer R225, Var Bal 1, located in the collector circuit of transistors Q210A, and Q210B, is adjusted with no input signal to set the voltage across the Variable VOLTS/DIV control, R264, in the Output Amplifier stage to zero volts. With both sides of the amplifier balanced, trace deflection is prevented as the Variable VOLTS/DIV control is rotated throughout its range.

Normally, the frequency response of the Gain Switching Amplifier is from dc to at least 1 megahertz, however, for low-frequency applications where high input sensitivities are used, the overall frequency response can be limited to about 10 kilohertz to reduce noise referred to the input. This is achieved by pushing in the BW LIMIT 10 kHz switch, S239, which connects C239 across the output of the Gain Switching Amplifier.

### Isolation Stage

The differential signal developed at the collectors of Q210A and Q210B is passed through emitter followers Q242 and Q252 to the Output Amplifier. Transistors Q242 and Q252 isolate the Gain Switching Amplifier from the loading of the Output Amplifier and Trigger Amplifier.

### Output Amplifier

The Output Amplifier consists of push-pull amplifiers Q260 and Q270. With a signal applied, potentiometer R273, Gain 1,

provides emitter degeneration. The gain is determined by the total emitter resistance which allows the overall gain of the 5A26 to be adjusted to match the mainframe requirements. Also, the Variable VOLTS/DIV control, R264, provides continuously variable gain to 2.5 times the calibrated deflection factor setting.

Transistors Q267 and Q277 are positioning-current drivers. Position (POS) control, R274, provides an adjustable change in the conduction of the transistors to provide a current that either adds to or subtracts from the Q260-Q270 currents to alter the quiescent vertical position of the display.

### Channel Switching

Channel switching is accomplished by Q282, Q292, Q286 and Q386. The channel switch signal from the mainframe through pin B21 sets the bias on Q386 while the bias on Q286 is determined by the MODE buttons. The bias level at the base of Q286 relative to that at the base of Q386 determines which of these transistors is on. With the CH 1 MODE button pressed in and the CH 2 MODE button out, the bias level on Q286 is lower (more negative) than that at Q386, which turns Q286 off and Q386 on. With Q286 turned off, +5 volts dc through R286 reverse-biases diodes CR283 and CR293, which turns on Q282 and Q292 in the channel switch stage. Thus, the channel 1 signal is coupled to the mainframe through interface connector pins A7 and B7.

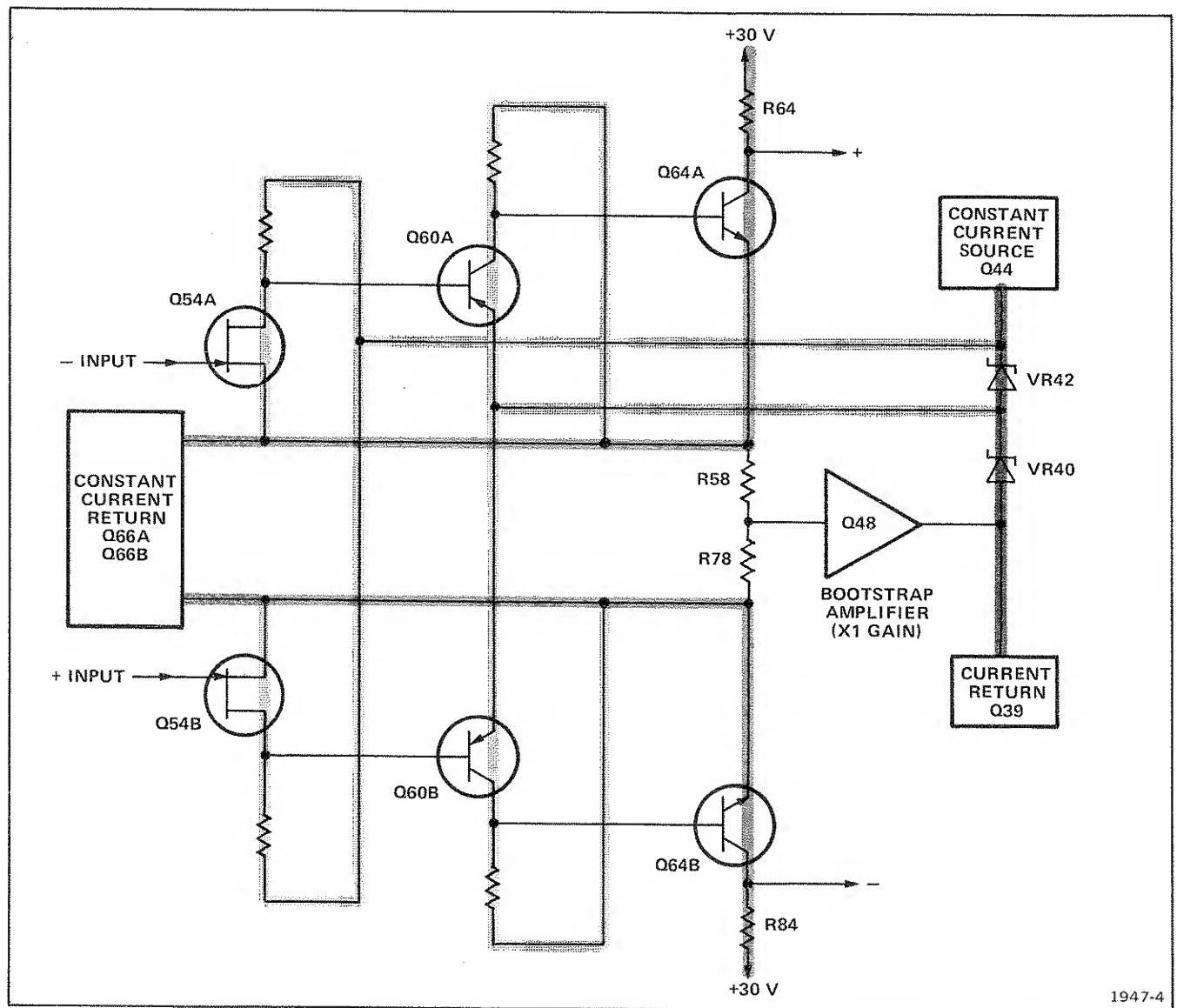


Fig. 2-1. Floating Power Supply detailed block diagram showing standing current paths through the Preamplifier.

While Q286 is off, Q386 is on and draws current from the +5 volt dc supply through R386. The resultant voltage across R386 turns off Q382 and Q392 in the Channel Switch stage. Thus, the channel 2 signal is not coupled to the mainframe.

When the CH 2 MODE button is pressed in, the bias level on Q286 is higher (less negative) than that at Q386, which turns Q286 on and Q386 off. The conditions described for the channel 1 mode are then reversed.

For dual-trace operation (both CH 1 and CH 2 MODE buttons pushed in), a 0 to +5 volts repetitive signal is applied from the mainframe to the base of Q386 through pin B21. Thus, the bias level on Q386 alternates above and below the bias level on Q286 which turns on channel 1, then channel 2, at a rate determined by the repetition rate of the channel switch signal at pin B21.

### Trigger Amplifier

Differential amplifier Q245 and Q255 receives the triggering signal from the emitters of Q242 and Q252 in the isolation stage of the Output Amplifier. The triggering signal is amplified and passed through TRIGGER switch S401 to transistor Q404 where it is made available to an associated time-base unit via pin A4. The triggering signal is of the same polarity as that applied to the gate of Q54B and has an amplitude of about 0.25 volts per displayed division.

### Vertical Switching

VOLTS/DIV switch S20 contains a series of cam lobes which engage and disengage various contacts at different positions of the switch. Cams 1, 2, 4, and 5 control switching of the Input Attenuator and cams 11 through 19 control switching of gain-setting network resistors R228 through R236 in the Gain-Switching Amplifier stage. Those contacts that are engaged at any VOLTS/DIV switch position are shown by black dots on the switch logic diagram.

## READOUT



### Deflection Factor (VOLTS/DIV Knob Skirt and CRT)

Either of two lamp bulbs (DS417 or DS421) located behind the VOLTS/DIV knob skirt illuminate the selected deflec-

tion factor to provide a direct readout. Normally, DS421 is lit to indicate a 1X deflection factor. Connecting a readout-coded 10X probe to either input (with the GND buttons out) automatically changes the crt readout by a factor of 10 and lights DS417 to indicate a 10X deflection factor.

With a 10X readout-coded probe connected to the — input, the probe-coding resistor is connected in parallel with R410 through the probe-coding ring. The probe resistor biases Q417 on, which turns on indicator DS417. Consequently, Q421 turns off and extinguishes indicator DS421. The probe-coding resistor in parallel with R410 also changes the bias on Q450 which changes the crt readout. When the DISPLAY button is out, illuminating voltage is removed from indicators DS417 and DS421, and Q484 is gated off. Thus, indicators DS417 and DS421 are extinguished, and the crt readout is blanked.

With a 10X readout-coded probe connected to the + input, R413 functions the same as R410 in the — input circuit. Thus, a 10X readout-coded probe connected to either or both inputs will provide a 10X readout on the VOLTS/DIV knob skirt and on the crt.

When pressed in, contacts of GND switches S2D (+ input) and S2B (— input) open the circuit between the + and — input probe-coding rings and the readout circuitry. Consequently, with a readout-coded probe connected to both inputs and both + and — GND buttons pressed in, the VOLTS/DIV knob skirt and crt will indicate a 1X deflection factor. If only one of the GND buttons is pressed in, the VOLTS/DIV knob skirt and crt will indicate a 10X deflection factor.

If the probe-coding ring on the + or — input connector is grounded, DS417 lights to indicate a 10X deflection factor and the crt readout is extinguished. The crt readout is determined by the VOLTS/DIV control which establishes the bias on Q458, Q466 and Q474. Changing the bias on the base of these transistors also changes the emitter voltage thereby changing the voltage across their associated emitter resistors. The current drawn from pin A28 through Q458, Q466, or Q474 and their associated emitter resistors determines the crt readout.

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